RELEASE AND ESTABLISHMENT OF *HARMONIA AXYRIDIS* (COLEOPTERA: COCCINELLIDAE) IN THE SOUTHEASTERN UNITED STATES[1]

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ABSTRACT: *Harmonia axyridis* were laboratory reared and 87,810 specimens were released (1978-81) primarily in pecan orchards containing leguminous cover crops at Byron, Georgia. The first major recovery indicating establishment in Georgia was in 1990 at Buchanan, 174 km from the Byron release site. By 1992, the population had spread throughout Georgia to northern Florida and eastern South Carolina. *H. axyridis* is now the dominant coccinellid species (54.4%) in the Byron pecan orchard and appears influenced by the legume cover crop. Numerous pecan growers in Georgia reported control of pecan aphids (*Monellia caryella* and *Monelliopsis pecanis*) during 1993. Adult *H. axyridis* were more attracted to white traps than to similar dark grey, brown, or black traps. During rearing, total development required ca. 36 d. Recorded prey include 36 species of Aphididae, 12 species from 7 other homopteran families, and 3 species from two other insect orders. Aphids appear to be preferred prey but all may be acceptable, indicating polyphagy and suggesting an extended control potential for this generally arboreal coccinellid.

Lady beetles in the genus *Harmonia* occur in Asia and Australia and prey on aphids, psyllids, and scale insects (Gordon 1985). Widely distributed in Asia, *Harmonia axyridis* (Pallas) is recorded from Formosa, China, Korea, Japan, Manchuria, southern Siberia and the Ryukyu and Bonin Islands (Chapin and Brou 1991). This arboreal species occurs in orchard and forest habitats and preys mostly on various aphids, but it will also accept certain scales and two species of chrysomelids. It inhabits various trees, including maple, walnut, willow, and oak (Chapin and Brou 1991). *Harmonia axyridis* is highly polymorphic, very prolific, and may live up to three years (Hodek 1973).

Several attempts have been made to introduce *H. axyridis* into North America. Inclusive dates for recorded releases include: California – 1916, 1964 and 1965; Connecticut, Delaware, Georgia, Louisiana, Maine, Maryland, Mississippi, Nova Scotia, Ohio, Pennsylvania, Washington, and Washington, D.C. – 1978 to 1982; and Connecticut – 1985 (Coulson *et al.*. 1981, Gordon 1985, McClure 1987; USDA, Beneficial Introduction Res. Lab., unpubl. records).

Recently, Chapin and Brou (1991) reported the establishment of *H. axyridis* in Louisiana and Mississippi. Releases in that area consisted of a single

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release of 32 specimens in Bossier Parish, Louisiana, in 1979 and eight releases totaling 3781 specimens in Washington County, Mississippi (near Leland), in 1980. The first evidence of establishment was the collection of more than 1000 adults in six light traps near Abita Springs, Louisiana, from July to November 1988. Specimens were collected from August to November 1990 in the Mississippi counties of Calhoun, Harrison, and Panola. In addition, Chapin and Brou reported specimens from crabapple trees infested with *Aphis spiraecola* Patch, crapemyrtle infested with *Tinocallis kahawaluokalani* (Kirkaldy), and from senescent *Erigeron* sp. in an old field habitat. Currently, *H. axyridis* is the most common lady beetle in the Abita Springs area.

This paper records the appearance of *H. axyridis* in Alabama, Georgia, South Carolina, and Florida. We also report on the rearing and release program in Georgia (Gordon and Vandenberg 1991, Tedders 1986, Tedders 1991) and give additional notes and information concerning its biology and behavior in Georgia and its known prey.

MATERIALS AND METHODS

Rearing and Production. An intensive *H. axyridis* rearing and release program was conducted at the USDA-ARS, Southeastern Fruit and Tree Nut Research Laboratory at Byron, Georgia, from 1978 to 1981. The target prey were black pecan aphid, *Melanocallis caryaefoliae* (Davis), blackmargined aphid, *Monellia caryella* (Fitch), and yellow pecan aphid, *Monelliopsis pecanis* Bissell, on pecan, *Carya illinoensis* (Wangenh.) K. Koch. Stock insects were supplied by the USDA-ARS Beneficial Insects Introduction Research Laboratory at Newark, Delaware. At Byron, most *H. axyridis* were reared on *Myzus persicae* (Sulzer) colonies that infested greenhouse-produced Chinese cabbage, *Brassica rapa* L. (*pekinensis* group). Chinese cabbage plants were grown in Jiffy-9® peat pellets. Additional fertilizer, fungicides, and insecticides were not used. Two tightly secured greenhouses were used, one to produce aphid-free cabbage plants and the second to produce cabbage plants infested with *M. persicae*. Non-infested plants were transferred to the second greenhouse where they remained for a few days and became infested. Aphid-infested plants were then removed and placed in individual cages containing one or more pairs of *H. axyridis* adults.

Cages for *H. axyridis* were 3.8 ℓ cylindrical cardboard cartons having a thin polyethylene upper cover that allowed for illumination and viewing. Newly infested cabbage plants were added to each cage every second day or as needed as aphids were consumed. Cabbage plants were provided in cages at the rate of one plant per pair of *H. axyridis*. Cabbage plants depleted of aphids were discarded. The inside of the carton cages were lined with brown wrapping paper as an oviposition substrate. Foliage, the paper liner, and the

cover were removed daily to obtain eggs for additional colony production for release, developmental studies, and studies of acceptance of pecan aphids as prey. Specimens of stock lady beetles were maintained in the insect collection at Byron as identification vouchers.

In the greenhouses, temperatures averaged 24.6°C (range 6.7 - 37.7°C) and relative humidity averaged 68.5% (range 30 - 100%). In the rearing facility the temperature averaged 23.6°C (range 20 - 27.7°C) and relative humidity averaged 69.4% (range 40 - 95%). Lighting was held constant by overhead lights 24 hr per day. The production cages often contained 2 or 3 pairs, and supply of food was increased at a comparable rate.

In November 1992, visual traps developed for monitoring the emergence of pecan weevils, *Curculio caryae* (Horn) (Stanley 1992, Tedders and Wood 1993) were used to assess visual color preferences. The traps were interlocking triangular masonite panels, measuring 53.3 cm base x 121.8 cm height, on top of which was positioned a modified boll weevil, *Anthonomus grandis grandis* Boheman, collecting device (Anonymous 1990). The panels were painted either white (84.0% reflectance), gray (18.3% reflectance), brown (4.8% reflectance), or black (1.0% reflectance). Each colored trap was replicated three times and set out across the lawn of the laboratory in a randomized complete block design. Traps were about 3 m apart. Traps were in place from about 3:00 p.m. November 17 until 3:00 p.m. November 20 (3 consecutive 24-hr periods). Beetles were removed and counted after each 24-hr period. Trap data were subjected to analysis of variance.

RESULTS AND DISCUSSION

Rearing and Development. Eggs were laid on the paper lining, cabbage foliage, and the polyethylene cover. A shortage of aphid prey in the cages was always followed by a marked reduction in lady beetle eggs due to cannibalism. Well-fed beetles did not usually cannibalize their own eggs.

Eggs averaged 4 days from oviposition to hatch (range 3-5 d). Average larval development for first through fourth stadia was 2, 2, 2-4, and 6 d, respectively, with larval development overall averaging 12-14 d. The pupal stadium ranged from 5-6 d and averaged 5.5 d. Average time required for development from egg to egg was about 36 d. Cooler temperatures ranging from 15.5 to 21.1°C increased the time required for development from egg to egg by 3-4 d.

Thirty-one newly emerged females were studied for longevity and fecundity. With one copulating pair confined per cage, females lived an average of 32.2 d (sd=25.26), laying an average of 491.3 eggs (sd=375.86); mean 16.7 eggs/female/d (sd=7.64). The shortest life span was 2 d and the longest 101 d. The 101-day old female produced 1543 eggs. Longevity of males was not recorded but was usually shorter than that of the females.

Adults and larval mortality in all colonies was usually the result of natural causes such as individual weakness and old age. Dead beetles were placed in a humidor and observed for suspicious microbial growth. On two occasions fungal pathogens were suspected and identified as *Paecilomyces farinosus* (Holm) Brown and Smith (Deuteromycota) (Richard A. Humber, pers. comm., Boyce Thompson Institute, Ithaca, New York).

All three species, *M. caryaefoliae, M. caryella*, and *M. pecanis* represented adequate food when time required for larval development and oviposition on a diet of *M. persicae* were used as baseline data. However, *H. axyridis* appeared to prefer *M. caryella.* The preference may be associated with the copious honeydew excreted by this aphid because both larvae and adults used this alternative food source. Adult *H. axyridis,* fed on *M. pecanis* or *M. caryella,* laid about 20 eggs per day. *Melanocallis caryaefoliae*, which appeared to be least favored as prey, excretes the least amount of honeydew.

Releases. Releases of reared *H. axyridis* in Georgia from 1978 to 1981 usually consisted of second and third instar larvae, occasionally 1st instar larvae, and rarely eggs. In total 87,561 immatures and 249 adults were released from 1978 to 1981 (Table 1). Releases were made on the farm at the Byron, Georgia laboratory, mainly into trees or legume cover crops within pecan orchards. Immatures were either transferred to plant foliage with a camel-hair brush, or the supporting substrate of Chinese cabbage leaf, paper liner, or polyethylene cage cover was stapled to pecan or legume foliage. Pecan trees were selected that supported *M. caryella, M. pecanis*, or *M. caryaefoliae* aphids or mixtures of two or all three species. The primary release orchard (about 7 ha) was bordered on opposite sides by oak-hickory-gum woods, on a third side by a second pecan orchard, and on the remaining side by a fallow field. No pesticides were applied to the orchard from 1977 through 1983.

Releases during March, April, and May were usually divided evenly between winter cover crop in the orchard and the pecan trees. The winter cover was composed of hairy vetch, *Vicia villosa* Roth, crimson clover, *Trifolium incarnatum* Roth, big flower vetch, *Vicia grandiflora* Scopoli, and rye grass, *Lolium* sp. Vetch and clover ground cover infested with pea aphids, *Acyrthosiphon pisum* (Harris), and occasionally cowpea aphids, *Aphis craccivora*, and *A. medicagenis* Koch was selected. Larvae and adults (n = 397) were released in nearby cultivated plums, *Prunus* sp., apple, *Malus* sp., and crapemyrtle, *Lagerstroemia* sp. Plums were infested with black peach aphids, *Brachycaudus persicae* (Passerini), rusty plum aphid, *Hysteroneura setariae* (Thomas), or *A. spiraecola.* Apple was infested with *A. spiraecola* and crapemyrtle with *T. kahawaluokalani.* Also, a total of 2,485 larvae were released in weed covers within pecan orchards where the dominant weeds were horseweed, *Erigeron canadensis* L., infested with *Uroleucon erigeronensis* (Thomas), cocklebur, *Xanthium strumarium* L., infested with *U. ambrosiae* (Thomas), and goldenrod, *Solidago* sp. infested with *U. rudbeckiae* (Fitch) (Table 1).

Initial Recoveries. From 1978 to 1981 attempts to recover adults of released *H. axyridis* were conducted weekly, beginning the first week of April and continuing until the end of October or mid-November depending upon the condition of pecan foliage and the weather. From 1982 to the present, collections of beneficial arthropods at Byron, emphasizing Coccinellidae and Chrysopidae, continued on the same schedule in the same 7-ha release orchard or in adjacent orchards not over 8 km distant. Given these efforts, if coccinellid establishment had been successful, beetles should have been detected.

From 1978 to 1981, three sampling methods were employed in the 7-ha orchard. Visual 2-hr searches were conducted weekly in and around the orchard. In addition, weekly sweep net samples of the ground cover (100 sweeps per 7 ha) were taken, and the lower limbs of 25 pecan trees within the orchard were jarred with a club to dislodge beetles onto a 1 m^2 cloth catching frame.

From 1982 to present, visual searches of about 1 hr were conducted monthly. Sweep net collections from cover crops continued but collections from trees were made with the aid of a D-Vac collecting machine as a substitute for the limb-jarring method.

After releases, mature larvae and pupae were easily found on foliage of pecan trees and the ground cover, however adults were scarce. One adult was swept from evening primrose, *Oenothera* sp., May 24, 1978. No adults were collected during 1979. Six adults were swept from vetch from April 28 to May 6, 1980, and fifty-three adults were collected from pecan foliage by jarring and by hand collection from May 5 to June 6, 1980. One adult was swept from rye grass on May 6, 1980. A single adult was recovered September 29, 1981, by jarring pecan foliage. No adults or larvae were collected from 1982 through 1991 .

Evidence of colonization in Georgia first became available in fall 1990. John C. Callaway, Jr., County Extension Director for Haralson and Carroll Counties (Buchanan, Georgia) advised the Department of Entomology, University of Georgia, Athens that an unidentified lady beetle had become a nuisance in houses in that area. A visit there on June 18, 1991 revealed a single *H. axyridis* adult on arrow leaf clover, *Trifolium vesiculosum* Savi. No additional lady beetles were found on adjacent trees, shrubs and other vegetation, but suspect pupal exuviae were found on apple. Specimens of that population submitted for identification to the Department of Entomology, University of Georgia, proved to be *H. axyridis* (Cecil L. Smith, per. comm.).

A second trip to Haralson County (elevation 382 m) on November 12, 1991, revealed about 50 *H. axyridis* adults inside the screened porch of a home in Buchanan. Additional searches revealed numerous adults and pupae on apple, *Pinus* spp., and magnolia, *Magnolia macrophylla* Michaux, at this site. During November and December 1991 Mr. Callaway and the Byron Laboratory received numerous reports that *H. axyridis* was an increasing nuisance in

homes throughout northwest Georgia. During early winter of 1991 *H. axyridis* were identified from northeast Alabama and were abundant near Huntsville (Paul Estes, Auburn, Alabama, per. comm.).

Subsequent Recoveries–Biology and Population Abundance. At Byron, on February 4, 1992, one adult was collected from loblolly pine, *P. taeda* L. that was heavily infested with *Eulachnus agilis* (Kaltenbach) on which the beetle was feeding. Thereafter and throughout March adults, larvae, and eggs were found regularly on various species of yellow pine infested with *E. agilis*. Foliage samples from April through October 1992 revealed that *H. axyridis* began inhabiting pecan in May and fluctuated in numbers as aphid populations varied. *Harmonia axyridis* comprised 54.4% of all the lady beetles collected from pecan by the end of the growing season (Table 2).

In a separate experiment on October 6, five terminal branches on each of 20 pecan trees were examined for *H. axyridis* by the jarring technique. Adults averaged 0.30/terminal and larvae 0.27/terminal. Aphid control on pecan, which was considered to be very good throughout 1992, was attributed mainly to *H. axyridis* .

By late summer 1992, specimens of *H. axyridis* were found throughout Georgia (W. L. T.), in north Florida (Russ Mizell, University of Florida, pers. comm.) and near McClellanville, South Carolina (Stuart H. Tedders, University of South Carolina, pers. comm.).

Movement by *H. axyridis* to overwintering aggregation sites began about November 1, 1992, when several hundred were found on the southwest sides of several buildings at Byron. On November 17 adults were observed flying around the grounds of the laboratory in such abundance that they were first thought to be the tail end of a swarm of honey bees. Many of these landed on the sides of buildings in large numbers, and four people were able to hand collect about 6,000 beetles in $2^1/_2$ hrs.

Since beetles appeared to be attracted in greater numbers to light colored buildings than to dark colored ones, it was not surprising that traps captured totals of 208, 143, 61, 23 in the white, gray, black, and brown traps, respectively. Analysis of variance of these data indicated that *H. axyridis* is significantly attracted to white traps ($\alpha = 0.05$) as opposed to darker ones (Table 3). This finding confirms observations by Obata (1986) in Kyoto, Japan, and agrees with those of Hodek (1973) that several coccinellid species were attracted to light-colored rock outcroppings that were used as overwintering sites. Beetles were not observed moving to overwintering sites after November 20, 1992.

Recoveries began in 1993 when several adults were found (February 15) feeding on the floral nectaries of common box, *Buxus sempervirens* L., indicating that emergence from overwintering had begun. About 2,000 hibernating adults were collected on February 26 by three people in 30 minutes from the center of a panelled wall on the south-southwestern side of an abandoned

insecticide building at the laboratory farm center, indicating that most were still overwintering. Also on that date, several active adults were observed on yellow pine, and about 30 active adults were observed on the lighting fixtures in an office of the laboratory building, further indicating that the overwintering period was ending.

At Biloxi, Mississippi (February 28), mature larvae, pupae, and newly emerged adults were found on *Podocarpus* sp. infested with *Neophyllaphis podocarpi* Takahashi at a hotel resort facing the Gulf of Mexico, confirming that *H. axyridis* had been active in that area for several weeks, and had passed through at least one generation (W.L.T.).

On March 9 at Byron, adults were observed feeding on exudates of the floral nectaries of peach, plum, and common box. Aphids or other prey were not observed on these plants, and we can exclude the possibility that aphid eggs were being fed on since aphids are rare on these plants in central Georgia. On March 11, 100 limbs each of peach, plum, and yellow pine were jarred revealing 13, 1, and 3 adults, respectively.

Impact in Pecan orchard: Collections of *H. axyridis* from pecan orchards at Byron continued during 1993. In addition to standard sweep net and D-Vac machine samples, a large Malaise trap was placed in a legume ground cover study orchard. Collections from this orchard were compared, with collections from an adjacent control orchard without a legume cover. Yellow aphids on pecan in the legume cover crop orchard were very low, the highest count averaged only 4.7/compound leaf during the week of May 10. Average numbers of aphids for May 1993 was 2.2 aphids per compound leaf. Yellow pecan aphids on pecan during May usually exceed 100/leaf. In the adjacent control orchard the highest counts were 22.3 aphids per compound leaf during the week of May 17, and counts averaged 9.2 aphids per compound leaf for the month. Neither orchard received insecticide but *H. axyridis* were noticeably slower to colonize the non-cover crop orchard. Although a Malaise trap was not used and sweep net samples were not taken from the closely mowed grass of the control orchard, comparative collections of *H. axyridis* suggest the importance of the legume cover crop (Table 4). Numerous pecan growers in Georgia reported excellent control of *M. caryella* and *M. pecanis* in commercial orchards during 1993 (W.L.T.).

Conclusions: *Harmonia axyridis*, first reported to be established in North America by Chapin and Brou (1991) from Louisiana in 1988 with subsequent collections during 1989 and 1990, was not reported in Mississippi until 1990. There was no mention by the authors of the size of that population. Releases possibly leading to the Louisiana-Mississippi establishment were a single release of 32 specimens in Bossier Parish during August 1979 and eight releases of 3781 specimens from July to October 1980 near Leland, Mississippi. The straight-line distance from Bossier City (Bossier Parish) to Abita

Springs, Louisiana is about 418 km (260 mi) and from Leland to Abita Springs is 320 km (199 mi). The distance from Leland and Bossier City to Buchanan, Georgia is about 553 km (344 mi) and 831 km (516 mi) respectively, and from Abita Springs to Buchanan is about 591 km (367 mi) (Figure 1).

The population level first reported in Georgia near Buchanan during the fall of 1990 was very high as judged by numerous calls to county agent John Callaway in Buchanan (personal communication). The straight-line distance from Byron to Buchanan is about 174 km (108 mi). It remains uncertain whether the Buchanan population was the result of migration of beetles across Mississippi and Alabama to Buchanan or the result of migration of releases from Byron to Buchanan. It is clear that many more specimens were released at Byron and the distance from Byron to Buchanan is much shorter. If the Buchanan population originated from Abita Springs, it is unusual that *H. axyrdis* were not reported as a nuisiance from Alabama before it was found in Georgia in view of its habit of overwintering in homes. The evidence suggests that two separate establishments occurred: one in Abita Springs, LA, and another in Buchanan, GA.

Because *H. axyridis* is highly polymorphic, with a basic red morph and a black morph, as illustrated in Ayala (other variations are also possible), it is important to record that no black morphs were found in Georgia, Alabama, Florida, and South Carolina populations. All beetles found to date are of the red color morphs as described by Chapin and Brou (1991). Live specimens of red morph vary in background color from a pale yellow-orange to a deep orange-red (which may well be age related), and the black spotting varies from none to 20± spots.

As *H. axyridis* spreads from the southeast into other areas and begins to receive increasing attention, a greater understanding of this invading species will result. Toward that end, we present a rapidly growing list of prey species (Table 5). This tentative list will serve as a reference point for addition of new prey species, especially as this lady beetle is redistributed (See Appendix) and spreads naturally into new states.

APPENDIX

In light of some significant biological information and records of an intentional shipment of *Harmonia axyridis,* we offer the following information for the record.

Biological Notes: April 16, 1980, freeze-dried pea aphids and a water supply were found to be acceptable but poor quality food for *H. axyridis* . Thirty-six eggs yielded five pupae but only three adults.

1980–*Uroleucon ambrosiae* on horseweed and cocklebur were unsatisfactory prey and *H. axyridis* did not complete development. *Uroleucon erigeronsis* on horseweed were fair prey and produced adults after lengthy feeding.

Aphis craccivora on vetch and velvet bean, *Stizolobium Deeringianum* Bert., were poisonous to *H. axyridis* larvae. *Aphis spiraecola* on Garland cv. crab apple, *Malus coronaria* Mill. were poor prey for larvae.

May 22, 1981–*Phylloxera notabilis* Pergande on pecan were excellent prey for *H. axyridis*; larvae matured in less that 12 d. Field released adult *H. axyridis* were observed feeding on *P. notabilis* emerging from opening galls.

August 25, 1981–*Tinocallis kahawaluokalani* on crapemyrtle were suitable prey. Larvae released on crapemyrtle yielded at least two adult *H. axyridis* . Four *H. axyridis* adults fed *A. pisum* laid a total of 2,016 eggs; average 526.5 eggs/female over a period of 32.3 consecutive days. As prey, *A. pisum* were deemed suitable.

For initial rearing of *H. axyridis* in quarantine at Newark, prey were *A. pisum* produced on faba (fava) beans, *Vicia faba* L. Cages for all life stages were 530 cc unwaxed paper cups (No. 2186 Design, James River Corp.) with tight-fitting clear plastic lids. To prolong the availability of suitable *A. pisum* prey, several lengths of bean stems were stripped of leaves and placed in each cup. By stripping stems of leaves, the containers were kept cleaner, which facilitated detection and removal of eggs, larvae, and adults.

Samples of overwintering *H. axyridis* were weighed on two occasions after collection to gain information about weight loss during hibernation. On December 15, 1992, 315 beetles weighed an average of 35 mg. On January 11, 1993, 224 beetles weighed an average of 33 mg for loss of 2 mg over 27-d period.

May 1993–All stadia of *H. axyridis* were found in very large numbers on six tulip trees, *Liriodendron tulipifera* L., infested with *Macrosiphum liriodendri* (Monell) in Houston County, Georgia.

April 1993–Ornamental rose, *Rosa* spp., infested with *Rhodobium porosum* (Sanderson) were found to have one or more feeding adult or larval *H. axyridis* per plant in Thomasville, Ga. The *H. axyridis* population was very large and effectively controlled aphids during this time.

Redistribution: Of the 8,000 *H. axyridis* adults collected during late 1992 and early 1993, 6,000 were sent to California for inspection and subsequent release in California and New Mexico pecan orchards (Ken S. Hagen, Kent Daane, and Steve Sibbett, University of California, pers. comm.). To date 1,500 were released on April 9 and 750 were released on April 30 at Blaine Ranch, Visalia, California. Dr. Hagan inspected and forwarded 2,000 to New Mexico where they were released in pecan orchards at Mesilla (Joe Ellington, New Mexico State University, pers. comm.).

During fall 1993, daily observations were made to detect the onset of *H. axyridis* flight to overwintering quarters. None were observed until November 4 when large numbers congregated on the sides of buildings at Byron (maximum air temperature was 22.2° C). Very few were observed on November 5

(maximum temperature 20.6° C) and fewer yet occurred during the next four days when maximum temperatures were 16.6° C or below.

Maximum flight activity occurred on November 10 when many adults congregated on the sides of buildings. Of particular interest that day was an abandoned silo located on the laboratory farm at Byron. The silo was a light gray concrete shell having no top and containing about 20 cm rain water at the bottom. Insects on the inside were inaccessible but visible through port holes. The silo measured 14.4 m cir. x 9.6 m height. At about 2:00 p.m., congregating *H. axyridis* were estimated at 1550 beetles/m2 on the outside wall with slightly smaller numbers on the inside wall. Air temperature for November 10 was 20° C maximum and 5° C minimum.

On November 11, entomologists Billy Ree and Allan Knutson of the Texas Agricultural Extension Service, Texas A&M University, arrived at Byron to collect *H. axyridis* during November 11-14. They collected 10,200 adults, mostly from the exterior wall of the silo. Maximum temperature for the period ranged from 19.4-25.0° C. Smaller numbers of adults were observed on the

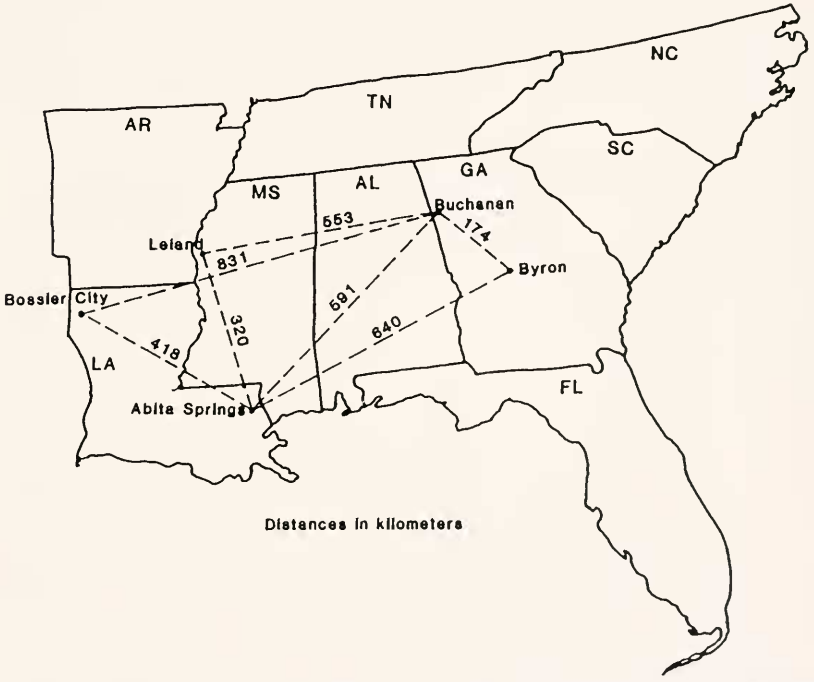

Figure 1. Map of Southeastern United States showing release sites (Byron, GA, Leland MS, and Bossier City, LA) and recovery sites (Buchanan, GA and Abita Springs LA) of *Harmonia axyridis* and the straight-line distances (KM) between sites.

silo on each successive day, but the change was not measured. On each day, the primary movement of adults to the silo occurred between 1:00 and 4:00 p.m. when air temperature ranged between 17.7-20.6° C. During that period, the sky was bright but large cumulus clouds intermittently blocked full sun. The greatest number of adults was observed flying to the silo during periods when the silo was fully illuminated, and flying decreased with shadows cast by clouds. Most *H. axyridis* that accumulated during the day were gone the following morning; presumably because of a lack of protected sites (cracks and crevices) to inhabit. The *H. axyridis* collection was returned to Texas for study and release in Texas pecan orchards during spring 1994. One Byron technician collected 2795 *H. axyridis* from the silo for our use on November 12 during a 1.5 hr. period. Adult weight averaged 35.4 mg.

Table 1. Release of *Harmonia axyridis* into pecan trees and clover-vetch ground cover, Byron, Georgia.

	1978		1979		1980	1981
	Immatures	Adults	Immatures	Adults	Immatures	Immatures
Mar.					23,401	
Apr.	197	34	1,767	6	6,729	
May	1,195[1]	162[2]	723	18	1,052	
Jun	2,496	6				
Jul	482					
Aug	258[3]		12,164			
Sep	2,780		2,145[4]			933
Oct	2,846	23	15,244			809
Nov			12,318[5]		22	
Total	10,254	225	44,361	24	31,204	1,742

[1] 201-plum, 172 apple
[2] 18-apple
[3] 6-crapemyrtle
[4] 540-weed cover
[5] 1,945-weed cover

Table 2. D-Vac collections of important Coccinellidae from pecan trees at Byron, Georgia, 1992.

Species	Month/Number Collected							
	Apr	May	Jun	Jul	Aug	Sep	Oct	Total
Hippodamia convergens	0	4	2	2	0	0	0	8
Coccinella septempunctata	2	16	8	5	1	2	0	34
Olla v-nigrum	1	4	5	4	16	2	1	33
Cycloneda munda	3	6	2	3	3	1	1	19
Coleomegilla maculata	0	0	1	4	0	0	11	16
Harmonia axyridis	0	2	0	9	53	34	34	132
Total	6	32	18	27	73	39	47	242

Table 3. Analysis of variance of means of numbers of *Harmonia axyridis* adults captured in four different colored traps November 17-20, 1992, Byron, Georgia[1].

Trap	24 hr periods[2]			Total of 3
Color	1	2	3	Period[3]
White	5.4 a	5.6 a	2.6 a	8.1 a
Gray	4.3 ab	4.2 a	2.1 ab	6.6 ab
Black	2.8 bc	3.0 ab	17 ab	4.5 bc
Brown	2.0 c	1..3 b	0.7 b	2.8 c
MSE	0.899	1.767	0.592	2.164

[1] Analysis of variance of means; $\alpha = 0.05$, df = 6. Means followed by same letter within a column are not significantly different (Duncan's Multiple Range Test).

[2] Means captured in 3 traps per 24 hr period.

[3] Means captured in 3 traps per 72 hr period.

Table 4. *Harmonia axyridis* captured in pecan orchard with ground cover of crimson clover and hairy vetch, sampled by malaise trap, sweep net, and D-Vac methods, compared with adjacent orchard with no cover crop, sampled by D-Vac only, Byron, Georgia 1993.

	Legume Cover Crop Orchard			No Cover Crop
Sample Period	Malaise Trap	Sweep Net[1]	D-Vac[2]	D-Vac[2]
Mar 8-14	—	2	—	—
Mar 15-21	0	1	—	—
Mar 22-28	2	2	—	—
Mar 29-Apr 4	8	10	—	—
Apr 5-11	4	23	—	—
Apr 12-18	8	3	3	0
Apr 19-25	6	5	2	1
Apr 26-May 2	0	3	4	1
May 3-9	1	0	1	1
May 10-16	0	0	2	1
May 17-23	0	1	0	1
May 24-30	0	1	3	0
Total	29	51	15	5

[1] Sweep net samples represent 5 sweeps in each of 10 locations.
[2] D-Vac samples represent 5 terminals/tree from each of 10 trees.

Table 5. Recorded prey of *Harmonia axyridis* Pallas.

Taxon and Species [Source(s)][1]
Coleoptera:
Chrysomelidae
Ambrostoma quadriimpressum Motschulsky[4]
Chrysomela vigintipuncata Scopoli
Homoptera:
Adelgidae
Adelges laricis Vallot[4]
Aphididae
Acyrthosiphon pisum (Harris)[2,3] (Hodek 1973)
Agrioaphis spp. [4]
Amphorophora oleracea v.d. Goot[3]
Aphis craccivora Koch (Hodek 1973)
Aphis pomi DeGeer (Hodek 1973)
Aphis spiraecola Patch[2] (Chapin & Brou 1991)
Chaitophorus spp.[4]
Cinara kochi Inouye
Cinara laricicola (Matsumura)[3]
Cinara todocola (Inouye)[3]
Cinara pinea Mordvilko[4]
Cryptosiphum gallarum Kaltenbach[3]
Eriosoma lanigerum (Hausmann)[3]
Eulachnus agilis (Kaltenbach) (Present study)
Hyalopterus pinni Matsumura
Hyalopterus pruni (Geoffrey)[3]
Kermaphis pini (Koch)[3]
Lachnus sp.[3]
Macrosiphum rosae ibarae Matsumura[3]
Macrosiphum liriodendri Monell[2] (Present study)
Megoura viciae japonica (Matsumura)
Melanocallis caryaefoliae (Davis)[2] (Present study)
Monellia caryella (Fitch)[2] (Present study)
Monelliopsis pecanis Bissell[2] (Present study)
Myzus malisucta Matsumura[3]
Myzus persicae (Sulzer)[3] (Hodek 1973)
Neophyllaphis podocarpi Takahashi[2,3] (Present study)
Nippolachnus piri Matsumura[3]
Periphyllus californiensis (Shinji)[3]
Rhodobium porosum (Sanderson) (Present study)
Rhopalosiphum pseudobrassicae Davis[3]
Rhopalosiphum prunifoliae Shinji[3]
Schizaphis graminum (Rondani) (USDA, APHIS, Niles, MI)
Tinocallis kahawaluokalani (Kirkaldy)[2] (Chapin & Brou 1991)
Toxoptera odinae (Van der Goot)[4]
Toxoptera piricola Matsumura[3]

Table 5. Recorded prey of *Harmonia axyridis* Pallas (continued)
Taxon and Species [Source(s)] (continued)[1]

Diaspididae
Pseudaulacaspis pentagona (Targioni-Tozzetti) (Park and Kim 1990)
Lepidosaphes salicina Borchsenius[4]
Eriococcidae
Rhizococcus transversus (Green)[3]
Margarodidae
Icerya *purchasi* Maskell[3]
Matsucoccus resinosae Bean & Godwin[2] (McClure 1987)
Matsucoccus matsumurae (Kuwana) (Kao & Yun 1983)[4]
Phylloxeridae
Phylloxera notabilis Pergande[2] (Present study)
Pseudococcidae
Nesticoccus sinensis Tang[3]
Phenacoccus pergandei Cockerell
Psyllidae
Anomoneura mori Schwarz[3]
Thysanogyne limbata Enddeyein[4]
Lepidoptera:
Arctiidae
Hyphantria cunea (Drury)[5]

[1] Unless indicated otherwise, listed in Yasumatsu and Watanabe (1964) (citing other sources) as prey species in Japan.

[2] Prey species recorded in New World.

[3] listed in Chapin and Brou (1991) and citing other sources. Many other synonymous names are also given but these are not reproduced here.

[4] listed in Yan *et al.* (1989).

[5] Shu and Yu (1985).

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